LIFE CYCLE MANAGEMENT OF Z-BEE – AN ELECTRIC 3-WHEELER MADE OF POLYMER COMPOSITES

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ABSTRACT

Z-Bee is a new type of electrified vehicle concept that has been developed by the Swedish company, Clean Motion AB, using life cycle thinking. Z-Bee has a remarkably low emission factor of 0.014 kg CO_2 equivalents per km, including production and waste management. This is nearly ten times lower than the EU target of 0.120 kg CO_2 equivalents per km for all new passenger cars in 2012. The extremely low curb weight of approximately 160 kg has been achieved through employing solely composite materials into Z-Bee's body in white. The life cycle thinking also includes development of an efficient supply chain and development of recycling strategy for the end-of-life vehicle. This approach has shown to be successful in achieving the environmental efficiency.

INTRODUCTION

Environmental protection is a growing concern for many industries today, with emphasis on the reduction of carbon dioxide (CO_2) emissions in order to soften climate change. This is of particular importance for the transportation sector, which is currently one of the greatest contributors of anthropogenic greenhouse gas emissions within the European Union (EU). A contributing factor to the large emissions is that there are too many and too big vehicles for transportation. As a result, to transport a liter of milk home from the store we use a tool weighing 1500 times the weight of the transported goods.

Z-Bee (see Figure 1), an electric 3-wheeler with a curb weight of approximately 10% of a normal car, with electric drive and no tailpipe emissions has been developed by Clean Motion AB. For the minimal energy consumption, the body in white of the Z-Bee is made of fibre reinforced plastic (FRP) sandwich.

Figure 1. Z-Bee - an electric 3-wheeler.

The objective of the LCA study is to understand the environmental impacts of the Z-Bee vehicle in a life cycle perspective, to give recommendations for the further product development. The study is focused on the composite parts of the vehicle, while the other non-composite components are considered more general due to the product development strategy at Clean Motion.

METHOD

For the current LCA study, input data has mainly been drawn from the commonly used LCA database Ecoinvent 2.2 (Swiss Centre for Life Cycle Inventories (ecoinvent Centre), 2010) and from Swerea IVF's own database. The LCA software SimaPro 7.3.3.2 has been used for the calculations. The Life Cycle Impact Assessment is performed using the guidelines from the International EPD Consortium (IEC, 2008) for values describing primary energy consumption, climate change and photochemical smog (emissions of solvents).

Functional unit

The functional unit is defined as the use of the Z-Bee for transport of one person 8000 kilometres, i.e. an approximate yearly use of the Z-Bee. The results are also expressed as the whole life cycle impact of Z-Bee, where the life length is set to 18 years.

System boundaries

System boundaries for the study are shown in Figure 2.

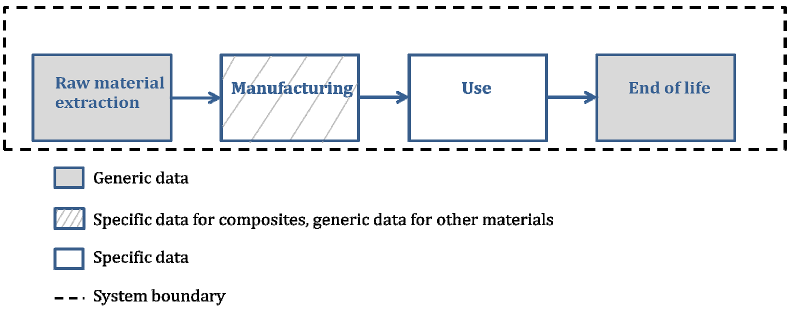

Figure 2. System boundaries for the Z-Bee study.

Life cycle inventory

The composite constituents have been modelled in detail using specific data from the suppliers to Clean Motion AB. All composites components are manufactured using vacuum infusion (Åström, 1997) at HJ Kompositmontering AB. The modelling of the non-composites components has been made by dividing the components into separate materials from which they have been manufactured. For electricity used in the use phase, Swedish average low voltage electricity has been used. For composites end-of-life, three different scenarios, namely mechanical recycling, incineration and landfill, are assumed based on literature as there are no facilities in commercial use in Sweden at the moment.

RESULTS

Impact assessment for Z-Bee's life cycle

The total global warming potential (GWP) for the cradle to grave life cycle of Z-Bee is 1 980 kg CO_2 equivalents. The manufacturing phase is the largest contributor, where the composite components and the battery are the dominant aspects. The use phase stands for 31% of the total life cycle impact on climate change. The negative result (-100 kg CO_2 equivalents) in Figure 3 a) for the end-of-life phase is due to avoidance of greenhouse gas emissions when virgin material is replaced by recycled material. The battery shows to have large impact on the whole life cycle result (27 % of the global warming potential) and should thus be modelled more detailed in future studies. For the primary energy consumption, it can be seen that the energy used in the use phase is 67% of the total primary energy use in the life cycle.

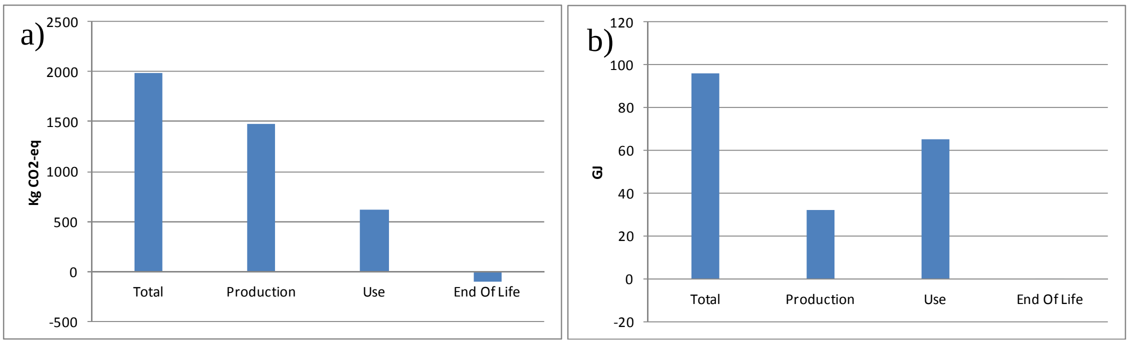

Figure 3. a) The global warming potential (kg CO_2-eq), b) primary energy consumption (GJ) in the life cycle phases of Z-Bee.

End-of-Life

The climate change potential for the 3 different waste scenarios used in the study is shown in Figure 4. The climate change impact category does not take into consideration all aspects of waste generation and management, such as land use and toxic emissions. However, in this particular work, the figure below shows that the best solution, incineration, renders a saved climate impact (due to energy recovery) of 15 kg CO_2 equivalents. This is not a large number compared to the climate impact of 2 tonnes CO_2 equivalents from the life cycle as a whole.

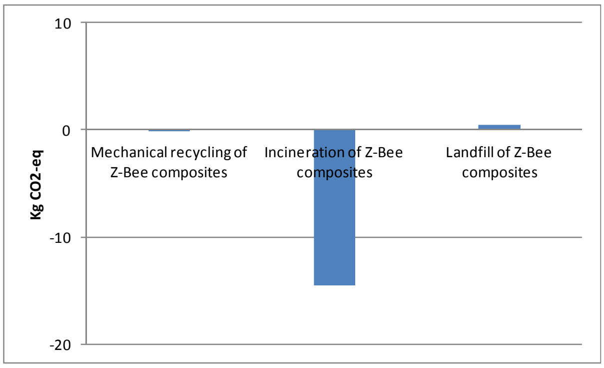

Figure 4. Climate change potential for the different waste scenarios considered in the study.

DISCUSSION

A life cycle assessment (LCA) from cradle to grave has been performed on Z-Bee vehicle, an electrified three-wheeler made of polymer composites. The results show that Z-Bee has a remarkably low emission factor of 0.014 kg CO_2 equivalents per km, including production and waste management. This is nearly ten times lower than the EU target of 0.120 kg CO_2 equivalents per km for all new passenger cars in 2012. Concerning the waste treatment, the global warming potential, which is the main focus in this study, is not the key environmental aspect. Instead, it is the use of land area for landfill, leakage of acidifying, corrosive and toxic substances. Also, the inability to recycle materials will lead to increased extraction of virgin material from the earth's crust, which is a concern commonly shared in discussions of end of life scenarios of products. For the comparison between the different components, it should be noted that some of the figures are built on data from the material supplier and some on data from generic databases, which have direct influence on the accuracy of the results.

CONCLUSIONS

The results from the calculation of global warming potential on the Z-Bee vehicle give a total cradle to grave impact of 1 980 kg CO_2 equivalents. The use phase is no longer the dominant phase for the climate change potential as in the case of the conventional vehicles. Instead the manufacturing phase is the largest contributor, where the composite components and the battery are the dominant aspects.

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